UNIVERSITI PUTRA MALAYSIA

HARMONICS ANALYSIS AND DESIGN OF PASSIVE FILTER FOR LOW VOLTAGE DISTRIBUTION SYSTEM

CHAN CHEE MENG

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By

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Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Science in the Faculty of Engineering Universiti Putra Malaysia

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DEDICATION

This report is dedicated to
my lovely wife Siew Choo,
for her patience and understanding
during the preparation of the manuscript,
and to my beautiful children,
Yi Khai and Hui Juan.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of requirement for the degree of Master of Science.

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Chairman: Norman Mariun, Ph.D, P.Eng.

Faculty: Engineering

Power quality is an important and growing concern for utility and facility engineers. The power problems are further aggravated with the rapid increase in the utilisation of non-linear devices. Non-linear devices like computer, uninterruptable power supply, electronic lighting ballast, and motor controller generate harmonics which can put thermal stress on cables and electrical equipment. In addition, telecommunication systems may experience electromagnetic interference from the harmonic noise on the power line.

This report presents the harmonic distortion signatures and characteristics of low voltage single-phase and three-phase non-linear loads and suggest the parallel-tuned passive filter as a means to mitigate the harmonics. The recognition of the harmonic signatures, characteristics, symptoms, and an appropriate duration of power quality

monitoring will enable the maintenance personnel a quicker and more effective diagnosis to a harmonic-related power quality problem.

Most domestic electrical appliances have a switched-mode power supply. The SMPS generates predominant 3^{rd}, 5^{th}, 7^{th}, and 9^{th} harmonic components with the 5^{th} harmonic as the most significant harmonic voltage component and the 3^{rd} harmonic as the most significant harmonic current component. The connection of different types of single-phase non-linear loads to the same power line generates a resultant harmonic profile, which may differ from the individual harmonic profile.

Three-phase non-linear loads like the AC-AC and AC-DC drive machines have their own harmonic profile. For the same type of variable speed drive, a six-pulse and a twelve-pulse converter drive, the harmonic profiles are also different. A six-pulse converter drive draws a series of odd harmonic currents, with the 5^{th}, 7^{th}, 11^{th}, and 17^{th} harmonics as the most significant harmonic components. The most significant harmonic components of a twelve-pulse converter drive are the same but of lower magnitude. Normally, the drives are connected to a three-phase three-wire power system therefore the triplen harmonic currents will not flow out of the system.

The single-phase filter unit design consists of a two-stage filtering circuit. Each stage is a parallel-tuned passive filter tuned to the 3^{rd} and 5^{th} harmonic frequencies. Simulation results indicate the effectiveness of the filter unit to trap the 3^{rd} and 5^{th} harmonic currents. Hence, the 3^{rd} and 5^{th} harmonic currents from single-phase loads

will be prevented from flowing back into the power system, resulting in an overall reduction of the 3rd and 5th harmonics in the neutral conductor.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

ANALISIS HARMONIK DAN REKA BENTUK PENAPIS PASIF UNTUK SISTEM PENGAGIHAN VOLTAN RENDAH

Oleh

CHAN CHEE MENG

Disember 2000

Pengerusi: **Norman Mariun, Ph.D, P.Eng.**

Fakulti: **Kejuruteraan**

Kualiti kuasa adalah penting kepada jurutera fasiliti. Keprihatian terhadap ciri ini semakin bertambah serius. Masalah kuasa menjadi lebih serius apabila peralatan-peralatan tak lelurus digunakan dengan begitu banyak. Peralatan-peralatan tak lelurus seperti komputer, bekalan kuasa tanpa gangguan, lampu balast elektronik, dan pengawal motor menghasil harmonik yang boleh memberi kesan terma pada kabel dan peralatan elektrik. Selain itu, sistem telekomunikasi boleh mengalami gangguan elektomagnet daripada hingar harmonik yang ada pada talian kuasa.

Laporan ini menyampaikan tandatangan dan ciri-ciri harmonik yang dihasilkan oleh beban tak lelurus fasa tunggal dan tiga fasa serta mencadangkan penapis pasif tertala- selari sebagai satu cara untuk mengurangkan harmonik. Pengenalan tandatangan herotan harmonik, ciri-ciri, tanda-tanda serta tempoh pemantauan

harmonik yang memadai membolehkan personel baikpulih mengesan masalah harmonik dengan lebih cepat dan efektif.

Bekalan kuasa pensuisan(SMPS) adalah litar sepunya yang terdapat dalam kebanyakan perkakas domestik. SMPS menghasilkan komponen harmonik ke-3, ke-5, ke-7 dan ke-9 yang signifikan. Harmonik ke-5 ialah komponen harmonik voltan yang paling signifikan manakala harmonik ke-3 adalah paling signifikan bagi komponen harmonik arus. Beban tak lelurus fasa tunggal yang tidak sama jenisnya apabila disambungkan pada talian kuasa sepunya akan menghasilkan profil harmonik paduan yang beza daripada profil harmonik tersendiri.

Beban tak lelurus tiga fasa seperti mesin pemacu AC-AC dan AC-DC mempunyai profil harmonik tersendiri. Pemacu kelajuan boleh ubah yang sama jenisnya, pemacu penukar enam denyut dan dua belas denyut, mempunyai profil harmonik yang berlainan. Pemacu penukar enam denyut mengambil sederet arus harmonik ganjil dengan harmonik ke-5, ke-7, ke-11, dan ke-17 yang paling signifikan. Walaupun pemacu penukar mempunyai harmonik signifikan yang sama akan tetapi magnitudnya lebih rendah. Biasanya, pemacu-pemacu itu disambungkan pada sistem fasa tiga dawai tiga. Oleh itu arus harmonik ke-3 dan penggandanya tidak akan mengalir ke luar sistem itu.

Unit penapis fasa tunggal yang direkabentuk mengandungi dua peringkat penapisan. Setiap peringkat penapisan mempunyai satu litar penapis pasif tertala-selari yang

ditalakan kepada frekuensi harmonik ke-3 and ke-5. Keputusan simulasi dapat menunjukkan keberkesanan unit penapis itu untuk memerangkap arus harmonik ke-3 dan ke-5. Dengan demikian arus harmonik ke-3 dan ke-5 yang dihasilkan oleh beban-beban fasa tunggal dapat disekat daripada mengalir balik ke sistem kuasa. Akibatnya jumlah arus harmonik ke-3 dan ke-5 di konduktor neutral dapat dikurangkan.

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Last but not the least, my heartfelt appreciation to the technical staffs of the Electrical and Electronic Engineering faculty and my colleagues.

I certify that an Examination Committee met on 18th December 2000 to conduct the final examination of Chan Chee Meng, on his Master of Science thesis entitled "Harmonics Analysis And Design Of Passive Filter For Low Voltage Distribution System" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science.

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Date: 1 1 JAN 2001

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

Candidate
CHAN CHEE MENG

Date: 22/12/2000

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LIST OF ABBREVIATIONS

AC	alternating current
AVR	automatic voltage regulator
CRT	cathode ray tube
CT	current transformer
DC	direct current
IEEE	Institution of Electrical and Electronics Engineers
IEC	International Electrotechnical Commission
L	live
N	neutral
PC	personal computer
PCC	point of common coupling
RMS	root mean square
RSS	root of the sum of the squares
SMPS	switched-mode power supply
THD	total harmonic distortion
TNB	Tenaga Nasional Berhad
TV	television
UPS	uninterruptible power supply
VCR	videocassette recorder

CHAPTER 1

NON-LINEAR LOADS AND HARMONICS

1.1 Introduction

Electricity, a basic form of energy, has become a common and essential commodity to the modern world since Benjamin Franklin first discovered it in the eighteenth century. This invisible commodity is produced through various means such as hydroelectric generation, nuclear power generation, etc. It is transmitted and distributed by cables to its users. Though unseen by the naked eyes, its effects are put to beneficial use by men. It lights up homes, commercial centres and industrial sites and operates loads such as heater, motor, and computer. The amount of this unique commodity (AC power cannot be stored) produced, greatly depended on the need of the users' loads. The demand for this commodity is ever increasing through the years, making it an important criterion in power systems design. Power providers are not only concern with supplying sufficient quantity of electricity to their customers but also the quality of the supplied power. This criterion, power quality, is also taken seriously by the industrial and commercial customers of the power providers for it means less disruption or stoppage of their operations. Consequently, higher operational cost.

A perception on power quality is the cause of the power quality problem is due to the loads of the customers of the power providers. In time past, majority of the loads is of the linear type like the incandescent lamp and motor. These loads do not create

much of a problem on power system except when large motors are started. Large motor starting can be a cause of voltage sag on the power system. But now, approaching the twenty-first century, the increasing utilisation of power electronics in electrical motor drives and computers in the industries redefine the term linear load and reinforce the perception. The customer's load is longer linear in characteristics but non-linear that is, the relationship between voltage and current at every instant is not constant. The proliferation of these non-linear loads poses a new and challenging power quality problem to the power providers and customers. The supply voltage to these non-linear loads may be pure sinusoidal but the current waveforms of these loads are nonsinusoidal. The harmonic currents of these nonsinusoidal currents are injected back into the power system, which can cause failure or misoperation of equipment.

1.2 Project Objectives

This project has two objectives. The primary aim is to investigate the harmonics in power distribution systems and develop a profile on harmonic distortion. The second objective is to develop a harmonic mitigation device. To achieve these objectives, the following works were carried out.

- Simulation of harmonics characteristics in single-phase and three-phase power distribution system.
- Real-time measurement to develop the harmonic profile in a domestic environment.